Center for Multiscale Modeling of Atmospheric Processes (CMMAP), Colorado State University - A National Science Foundation (NSF) Science and Technology Center

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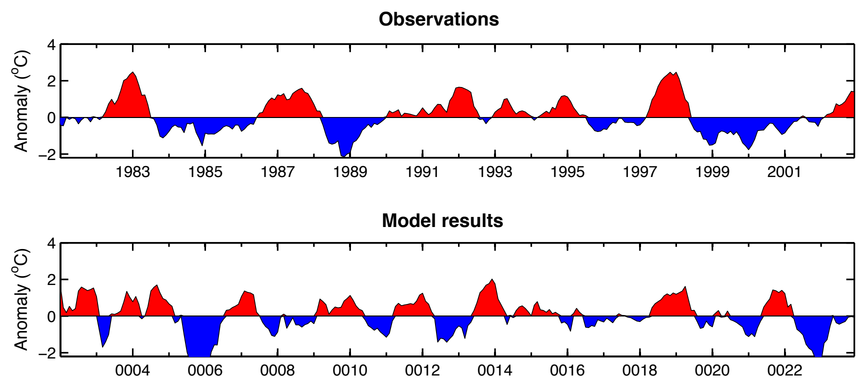
A Coupled Atmosphere-Ocean Model with Explicit Clouds

The Earth's climate results from complex interactions between the atmosphere, the ocean, and the land surface. CMMAP's research is focused on new approaches to simulating cloud formation in the global atmosphere. CMMAP has created a new "Multiscale Modeling Framework," or MMF, in which clouds are explicitly simulated by embedding a fine-grid cloud-resolving model within each of a global atmospheric model's much larger grid columns. Until recently, CMMAP has used the MMF to analyze how the explicit clouds affect atmospheric phenomena such as tropical weather.

The effects of these explicit clouds on the simulated ocean are also critically important for climate simulation, however. These include cloud shadows, which reduce the solar radiation absorbed by the ocean. The clouds also influence large-scale weather systems, which in turn affect the ocean through surface wind stresses.

Dr. Cristiana Stan of the Center for Ocean Land Atmosphere Interactions (COLA) coupled a global atmosphere model developed by CMMAP with an ocean model developed by the National Center for Atmospheric Research. The new coupled ocean-atmosphere model is called the SP-CCSM. Using the SP-CCSM, Dr. Stan performed the first-ever simulations in which the explicit clouds influenced the simulated ocean. A 20-year simulation produced with the SP-CCSM was compared with observations, and also with a control simulation obtained based on a conventional model. Two remarkable results were obtained.



Warm (red) and cold (blue) fluctuations of the sea surface temperature in the eastern Pacific Ocean, due to ENSO. The top panel shows observations, in which the sea surface temperature fluctuates on an irregular basis with a mean return time near four years. The bottom panel shows the results obtained with the SP-CCSM.

Permission granted

Credit: Cristiana Stan

First, the SP-CCSM immediately produced a simulation of the atmospheric general circulation that is significantly more realistic than that previously obtained with the MMF driven by observed sea-surface temperatures. The atmospheric simulation is particularly improved for the Asian summer monsoon, a gigantic weather system that brings life-sustaining rain to over a billion people. The immediate improvement in the model results is surprising, because experience shows that when an atmosphere model is first coupled with an ocean model, the simulated atmosphere typically becomes more realistic only after a lot of model "tuning" has been done. Dr. Stan did not tune the model at all.

The second major result, shown in the attached figure, is that the SP-CCSM produces a realistic simulation of the El Niño-Southern Oscillation (ENSO), considerably better than that of the conventional model from which it was derived. As is well known, ENSO produces strong effects on weather all over the world, including the United States. Stan and colleagues have shown that the SP-CCSM produces a realistic sea surface temperature climatology near the equator, which results from realistic simulated variability of the low-level winds.